CARLO GAVAZZI SPACE SpA

AMS02-TCS

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ACRONYMS

A	Analysis
AD	Applicable Document
AMS	Alpha Magnetic Spectrometer
AR	Acceptance Review
CAB	Cryomagnet Avionics Box
CDR	Critical Design Review
CGS	Carlo Gavazzi Space
CIL	Critical Items List
CoC	Certificate of Compliance
DIL	Deliverable Item List
EM	Engineering Model
FM	Flight Model
HTC	Heat Transport Capability
HW	Hardware
I	Inspection
LHP	Loop Heat Pipe
MOP	Maximum Operating Pressure
MOT	Maximum Operating Temperature
PA	Product Assurance
ROD	Review of Design
SDU	ShanDong University
SPA	Software Product Assurance
S/S	Subsystem
T	Test
TBC	To be confirmed
TBD	To be defined
TBU	To be updated

1. SCOPE

This document corresponds to contract deliverable DEL 067.

This document defines the requirements for the AMS-02 CAB Thermal Control System (CAB TCS), which is a part of the AMS thermal control system in order to transfer CAB heat dissipation to the relevant sinks.

The requirements have been derived from:

- Specifications of the CAB unit
- AMS system thermal specifications as far as applicable
- Updated thermal requirements and AMS Thermal Control Evolution

CAB TCS requirements are classified as follows:

- Applicable System Requirements
- Functional and Performance Requirements
- Lifetime and Reliability Requirements
- Design Requirements
- Resources
- Interface Requirements
- Environmental Requirements
- Assembly , Integration and Testing Requirements

2. DOCUMENTS

2.1 APPLICABLE DOCUMENTS

This document shall be read in conjunction with the documents listed hereafter, which form part of this document to the extent specified herein. In case of a conflict between any provisions of this document and the provisions of the documents listed hereafter, the content of the documents listed hereafter shall be considered as superseding.

2.2 APPLICABLE DOCUMENTS

AD	Doc.Number	Issue/Date	Rev.	Title/Applicability
1	AMSTCS-SP-CGS-003	25th March 2008 Issue 1	N/A	AMS02 Thermal Requirements Specification Document
2	[1]JSC-28792	March 2005	D	AMS-02 Structural Verification Plan for the Space Transportation System and the International Space Station.
3	JSC-29202	March 2005	C	Experiment/Vacuum Case Payload Integration Hardware Interface
4	DC-IPC-2007-062	\	\	CapitolatoTecnico "Progetto: AMS Attività di fase C/D" Doc. N. DC-IPC-2007-062
5	DC-IPC-2007-063	\	A	Tailoring di primo livello delle norme ECSS, serie M-E-Q – Progetto AMS attività di fase C/D
6	DC-IPC-2007-064	\	A	Product Assurance Requirements - Progetto AMS attività di fase C/D

2.3 REFERENCE DOCUMENTS

RD	Doc.Number	Issue/Date	Rev.	Title/Applicability
1	AMS-ID-CAB-00002-CRS	30th Nov. 2007 Iss2		AMS-02 CAB Interface Control Drawing
2	42-AMS02TCS-000-00-01	20th March 2008		WAKE Radiator ICD
3	JSC-63164	21st September 2005	\	Quality Management Plan for the Alpha Magnetic Spectrometer 02 (AMS-02) Experiment
4	CTSD-SH-1782	9/30/2005	\	Multi-Layer Insulation for the Alpha Magnetic Spectrometer Guidelines
5	JSC-29095	06/01/2002	A	Experiment/Payload Integration Hardware Interfaces - Part I
6	JSC-29095	August 2004	A	Experiment/Payload Integration Hardware Interfaces - Part II
7	SSP 57003	17/06/03	B	Attached Payload Interface Requirements Document
8	SSP 57004	13/06/03	B	Attached Payload Hardware Interface Control Document
9	JSC-49978	2006	\	Phase II Flight Safety Data Package for the Alpha Magnetic Spectrometer - 02 (AMS-02)

[1] SVP (Structural Verification Plan) for AMS can be found at http://ams-02project.jsc.nasa.gov/Documents/AMS-02%20SVP%20Rev%20E.pdf

RD	Doc.Number	Issue/Date	Rev.	Title/Applicability
10	JSC-63123	28th November 2005		Alpha Magnetic Spectrometer – 02 Assembly and Testing Integration Plan
11	E-mail to IE from A.Franzoso	21st August 2007		CAB-LHP Thermal model - PART 1 (CAB)
12	SEG39135726	March 8th 2007	B	Upper USS Assembly

2.4 SYSTEM DEFINITION

2.4.1 MISSION AND AMS SYSTEM DESCRIPTION

The international Alpha Magnetic Spectrometer experiment, AMS is a particle detector for high-energy cosmic rays. The scientific goal is to detect anti-matter, dark matter and lost matter. For this reason several detectors and sub-detectors operate in a magnetic field, which is generated by a super-conductive Helium-cooled magnet.

The experiment is designated AMS-02, since it is an improved version of AMS-01 flown on the Shuttle mission STS-91. AMS-02 is planned for a three to five years mission as attached payload on the ISS. The experiment is located on the ISS Truss structure as indicated in Fig. 2-1.

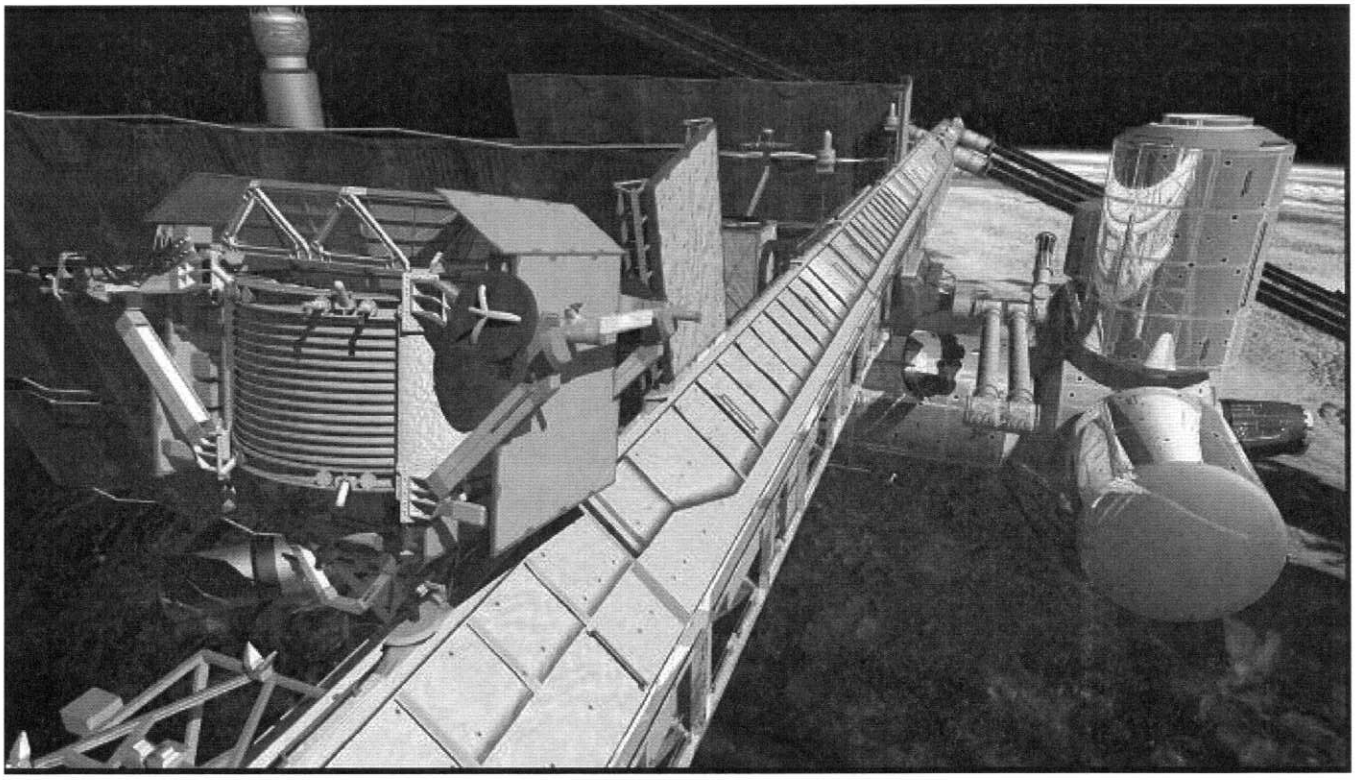


Fig. 2-1 AMS attached to the ISS Truss Structure

The overall experiment configuration is depicted in Fig. 2-2 and Fig. 2-3.

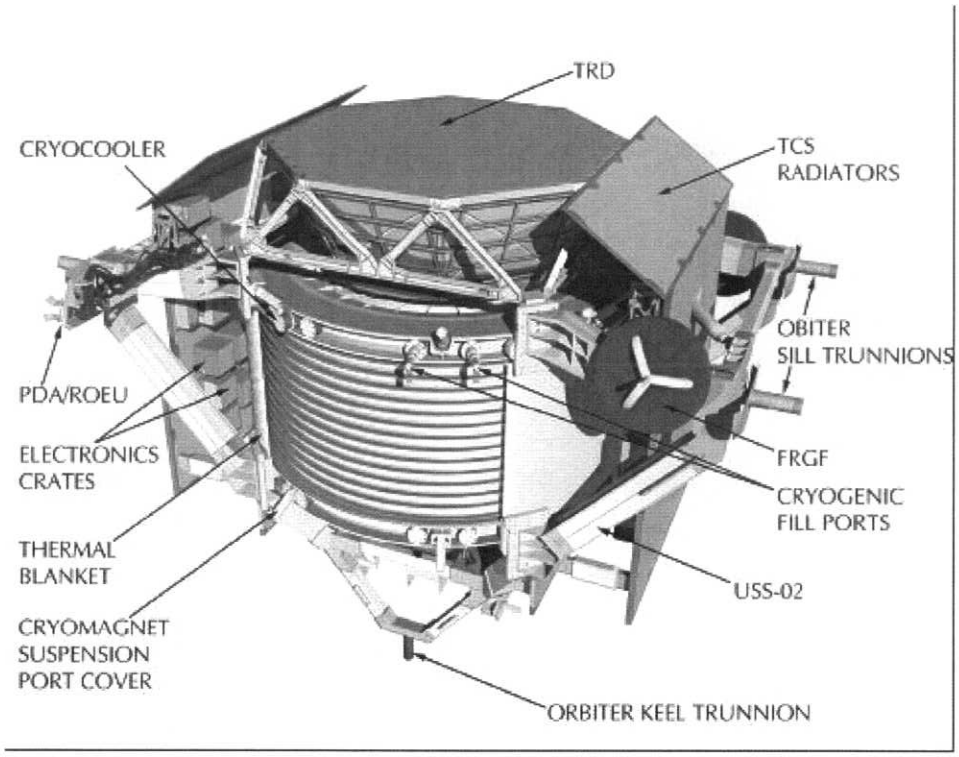


Fig. 2-2 Overall Configuration of AMS-02

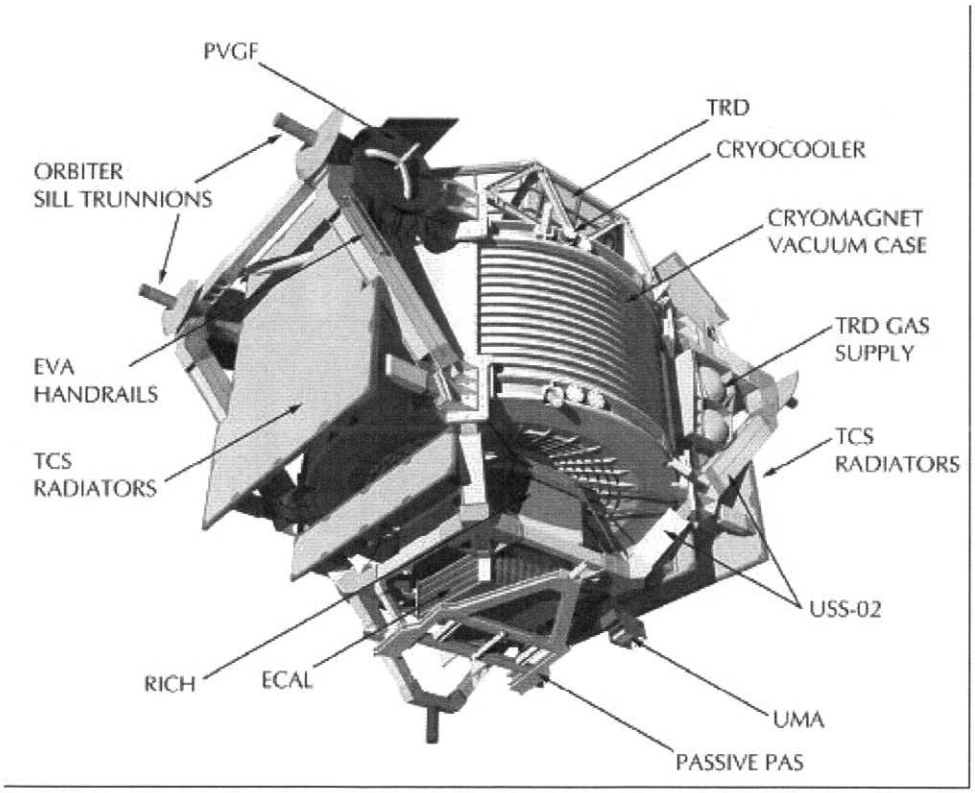


Fig. 2-3 Overall Configuration of AMS-02

2.4.2 CAB TCS DESIGN

Before starting the AMS-02 experiment it is necessary to charge the magnet. This will be performed by the CAB, which is mounted to the USS upper trunnion bridge on the WAKE side of the experiment (shown in Fig. 2-4).

The CAB TCS is composed by :

- 2 LHPs system
- Heat pipes mounted on CAB itself and on the USS to enhance the conductive heat exchange
- CAB radiative surfaces
- CAB heaters + mechanical thermostats
- LHP start-up heaters
- MLI

CAB LHP system consists of 2 sets of LHPs, one is the upper LHP and the other is the lower, with high-purity ammonia as heat carrier.

The condenser lines of upper LHP are fixed on the upper radiative side of WAKE Main radiator and the other is located on the lower section (shown in Fig. 2-4).

The material of the entire LHPs is stainless steel, except the evaporator saddle and the condenser saddles, which are aluminum alloy2.The LHP evaporator saddles are directly mounted on the CAB base-plate with screws; the corresponding condenser fluid lines are routed on the outside of radiative-side face sheet of the WAKE radiator, above some of the embedded HPs.

The condenser tubes are soldered to an aluminum saddle, which in turn is permanently glued (with a thermally conductive glue) to the Main Wake radiator. The saddle is secured to the wake radiator aluminum skin by some rivets to prevent the saddle / condenser assembly from becoming loose.

All the following figures represent the results of a still on-going design phase. Therefore, they must not be considered mandatory in terms of routing, size, accommodation.

The relevant requirements in terms of envelope, stay-out areas and overall design shall be properly identified in the requirements list.

[2] From corrosion point of view, all the 6000 series is OK, as per JSC 28792 Rev. E par. 12.3).
However, in order to allow structural calculation, the vendor has to provide the materials properties according to MIL-HDBK-5 (JSC 28792 Rev. E par. 12.1). In the MIL-HDBK-5 the only listed materials are 6013-6061-6151.
This is why CGS strongly suggests 6061. If an other alloy is chosen, it is not a problem in principle, but references and certifications of the material properties as specified in MIL-HDBK-5 must be provided.

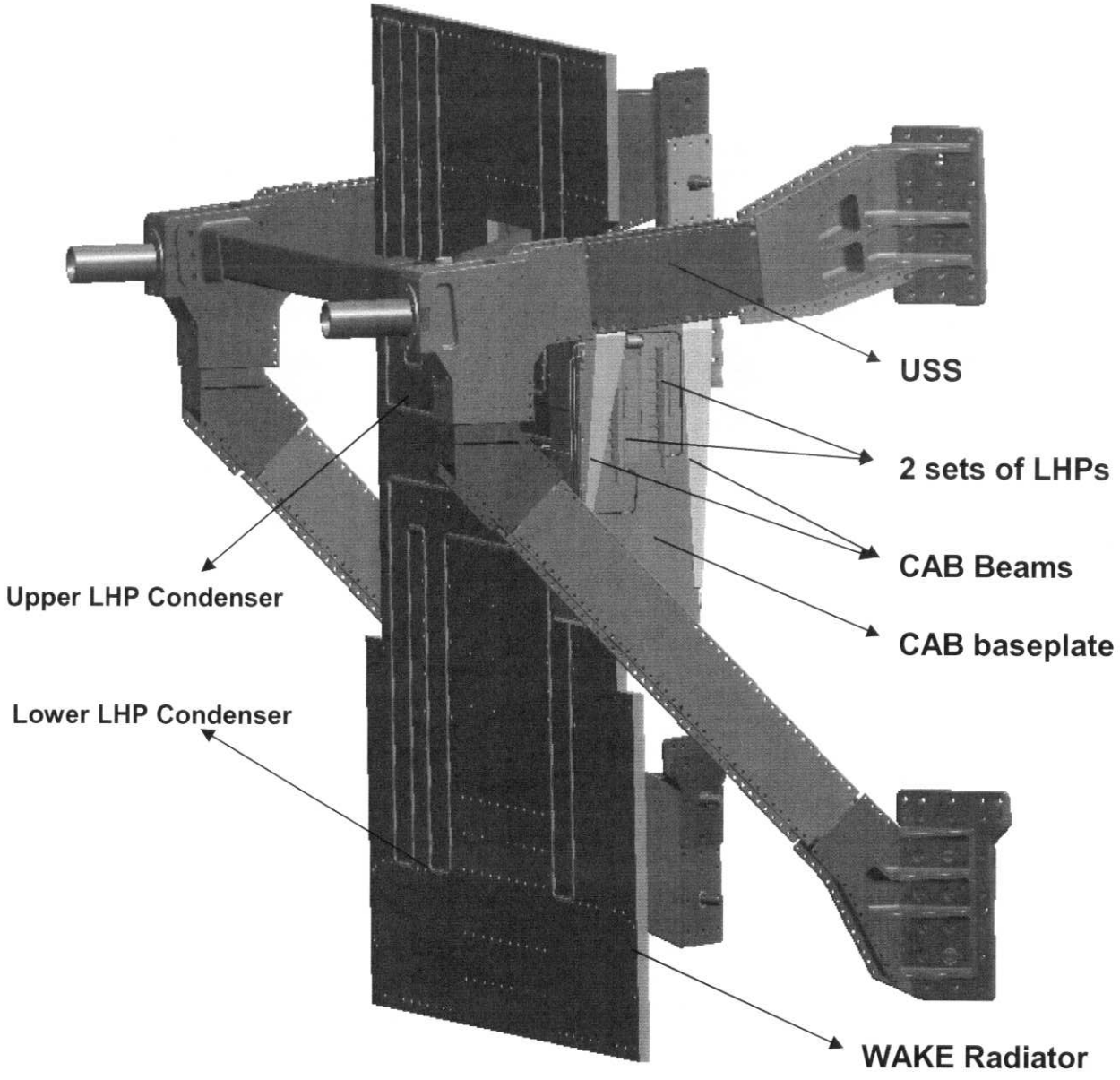


Fig. 2-4 Only for reference : CAB (with its beams, the yellow ones) and 2 sets of LHPs, the USS and the WAKE Main radiator

It has been agreed that the CAB on ground operations requiring the LHP running shall be performed with the system in horizontal position, with the AMS +X axis aligned with the gravity vector. Therefore, any previous constraint on the position of the compensation chamber with respect to the evaporator must be neglected. In particular, there is no need to have the CC above evaporator any longer.

For the thermal design it is preferable to have the LHP evaporators footprint as close as possible to the upper part of the CAB base-plate (compatible with the hole pattern available at CAB base-plate level), corresponding to the CCS CS converters mounting area – the most dissipating items during magnet charge. The new ground operations orientation (horizontal) allows the full satisfaction of this requirement. The evaporators shall be moved upwards as far as possible, in compliance with the mechanical constraints.

In order to prevent CAB temperatures to go below the minimum operating/non-operating temperature range, a passive bypass valve has been foreseen in the LHP design. The bypass valve shall decouple the evaporator from the condenser, short-circuiting the LHP lines.
The set point value shall be defined in the technical specifications of this document. In case the fluid temperature is below this set point (actually even higher than that) the valve closes the vapor line and the vapor flow to the radiator is consequently interrupted. This configuration prevents a rapid cool down of the CAB in case of system power outage. Considering that the switching of the valve from "ON" to "OFF" conditions occurs in a certain temperature range, we define the set point as the temperature at which the condenser line is completely closed, and the entire flow (in nominal conditions) is directed back to the Compensation Chamber through the bypass line.

The detailed design and the accommodation of the LHP compensation chamber and the by-pass valve are not defined and shall be the primary task of the LHP supplier.
As a starting point the present system-level design condenser footprint shall be considered. The condenser length shall be optimized during the early activities design phases.

In order to spread the heat all along the CAB chassis , 2 heat pipes running on the CAB unit shall be implemented: proposed locations are one the CAB top side, while the other is located on the rear (WAKE) side.
These heat pipes shall use ammonia as working fluid.

Part of the CAB dissipation shall be rejected to the USS, which serves as additional heat sink. In order to optimize the heat sink performance three heat pipes have been suggested to be mounted across adjacent USS parts (connecting the USS02 Upper Trunnion Bridge to the Upper Vacuum Case I/F joint), to increase conductance between the parts.
These heat pipes are custom-built and need to be folded in order to follow the USS profile.
The USS heat pipes working fluid is ammonia.
USS heat pipes shall be glued on the USS and an addition retention method shall be provided by a sustain bracket, which clamps the pipes on the USS.

CAB and LHP system shall be equipped with heaters as well.
The LHP heaters shall be start-up heaters and they shall provide the necessary power density on the evaporator saddle, needed to start the fluid circulation whenever needed.
The CAB heaters are switch-on and survival heaters. They shall provide means to reach the switch on of the unit and to protect it in the non operational phases. In this case the lines are controlled by mechanical thermostats.

Almost all CAB external faces shall be covered by Silver Teflon Tape to switch the original optical properties of the walls surface treatment to high emissivity / low absorptivity values.

Finally MLI shall be part of the CAB TCS.
CAB shall be partially covered by MLI blankets and MLI might be needed also (this shall be defined in the early phases of the design) in the exposed section of the LHPs transport lines and the portion running over the CAB, in order to keep the system operational even in the most severe cold environmental condition and during the cooling down scenarios.

In addition to Interface Drawings, CGS shall make available CAD models (in STEP format) with the mechanical interface definitions on CAB, WAKE Radiator and USS structure.

2.5 VERIFICATION METHODS

If not stated explicitly otherwise, each of the requirements in this specification shall be verified by a combination of, but at least by one of the following methods:

- Review of Design (ROD)

  Review of technical layout, functional descriptions, drawings and schematics.

- Analysis

  Thermal and structural analysis, etc.

- Test

  Environmental tests, performance tests, etc.

- Inspection

  H/W inspection, integration inspection, process inspection, etc.

- Similarity

  Similarity with similar qualifications or applications

The Verification of all the requirements, given in this specification, has to be documented. Any deviations has to be approved by CGS.

3. CAB THERMAL CONTROL SYSTEM REQUIREMENTS

This set of requirements applies to the CAB Thermal Control System, composed by 2LHPs , straight and bending heat pipes, Heater controlled by mechanical thermostats and suitable surface coated with high emissivity/low absorptivity tape.

3.1 TEMPERATURE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.1-010	CAB Max/Min Operational; Max/Min Non-Operational ; Switch-on Temperatures	The CAB TCS shall keep the CAB unit within the temperature limits reported in AD[1] in the relevant operative / non-operative modes (i.e. CAB power dissipation profile) under the defined/agreed cold and hot design cases.	Analysis	
AMS-CAB-TCS-3.1-020	Temperature sensors	The CAB TCS shall be equipped with temperature sensors located on the CAB LHP system. The temperature sensors shall be read-out by the Global Temperature Sensor Network	Review of Design	There are no temperature requirements associated to these sensors. These sensors are used for on-orbit evaluation of the correct behaviour of the CAB TCS system.

3.2 ENVIRONMENTAL REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.2 -010	ISS orbit requirements	The CAB TCS shall be designed to meet requirements of typical ISS low earth orbit. Where the main parameters of the ISS orbit are: Inclination: 51.6° Nominal Altitude: 400 km Orbit period: 90 – 93 min	Similarity	**Applicable to LHP supplier**
AMS-CAB-TCS-3.2 -020	Radiation	The CAB TCS shall sustain the total dose of radiation equal to 1 krad/year without degradation of performance.	Similarity	**Applicable to LHP supplier**
AMS-CAB-TCS-3.2 -030	Pressure	The CAB TCS shall withstand the following external pressure conditions: ● inside transport container (if used) and inside integration and launch side preparation facilities: ambient + 1 mbar ● during storage: ambient ● during launch: 1E5 Pa to 1 Pa within 80 s during ascent ● in orbit: vacuum of 1E-7 Pa over its lifetime	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-3.2 -040	Structural Verification philosophy	The CAB TCS shall be structurally verified considering CAB TCS in the final configuration installed on AMS02 Wake radiator; therefore the Main Radiators verification philosophy shall be applied.	ROD	
AMS-CAB-TCS-3.2 -050	Load factor and frequency limits definition	The CAB TCS design load factors definition and frequency limits are based on the AD[2].	ROD	

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.2-060	Frequency Verification	The CAB TCS system shall be verified by analysis if its fixed interface main frequency (modal effective mass greater than 5%) is analytically predicted above fifty (50) Hertz and by test if the analytical main frequency is below fifty (50) Hertz.	Analysis	
AMS-CAB-TCS-3.2-070	Design limit load factors	The CAB TCS is an AMS02 large secondary structure. For design and analysis purpose the design limit load factors listed in AD[2] shall be applied. These load factors include the effect of inertial loads and enforced displacement.	Analysis	
AMS-CAB-TCS-3.2-080	Safety factors	The minimum factors of safety (FS) for structural component design of the CAB TCS are 2.0 (ultimate) and 1.25 (yield) with no structural testing. For all the joints that do not have the matched drilled or reamed holes, a fitting factor of 1.15 shall be used for all modes of failure associated with structural joints, including bolts and bearing surfaces.	Analysis	

3.3 THERMAL MODELLING

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.3-010	LHP Thermal-fluidic model	The LHP supplier shall build and maintain an LHP thermal-fluidic model which shall be connected to an interface thermal model provided by CGS.	ROD	The LHP thermal-fluidic model is composed by evaporator bodies, transport lines and condenser lines for the 2 LHPs **Applicable to LHP supplier**
AMS-CAB-TCS-3.3-020	Interface thermal model	The Interface thermal model provided by CGS shall be in accordance to RD[11] and shall contain: - CAB reduced model - WAKE radiator reduced model - Local USS model - Environmental nodes (known also as MERAT nodes)	ROD	
AMS-CAB-TCS-3.3-030	Integrated Thermal model	The temperature requirements shall be verified by running the Integrated thermal model composed by the LHP thermal-fluidic model and the CGS Interface model.	Analysis	**Applicable to LHP supplier**
AMS-CAB-TCS-3.3-040	CAB TCS dimensioning environment	The CAB TCS thermal design shall be verified with Thermal Interface Data[3] provided by CGS applied to the Integrated Thermal Model.	ROD, Analysis	**Applicable to LHP supplier**

[3] The thermal Interface data are RD[10]. All the I/F data are time varying and are provided in SI units
The Thermal interface data set, provided on the basis of the orbital parameters defined above , are the result of an integrated thermal analysis with the ISS mathematical / geometrical models. The selection of the dimensioning cases is based on a screening survey.

3.4 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.4 3.3 -010	Mass	The total wet mass of the CAB TCS shall not exceed 4,2Kg including 2 LHPs, 2 CAB heat pipes, 3 USS heat pipes, tape on CAB surfaces and glue to attach the condenser lines to the WAKE radiator.	Analysis, ROD	MLI blankets are out of this budget. Their weight has to be included in a dedicate mass budget.
AMS-CAB-TCS-3.4 3.3 -020	CAB LHP Start-up heater power	The power available at each CAB LHP start-up heater shall not exceed 5W @113 Vdc.	ROD	
AMS-CAB-TCS-3.4 3.3 -030	CAB heater power	The minimum heater power available at CAB level for switch-on operations shall not exceed 100W @113 Vdc.	ROD	

3.5 ASSEMBLY, INTEGRATION AND TESTING REQUIREMENTS

ASSEMBLY

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.5 -010	CAB TCS assembly	The CAB TCS assembly shall be carried out by CGS.	ROD, Inspection	The CAB TCS Assembly consists in the fixation of the CAB TCS to the WAKE radiator and to the USS beam.

INTEGRATION

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.5 -020	CAB TCS integration	The CAB TCS Integration shall be carried out by CGS.	ROD	The CAB TCS Integration consists in the insertion of the CAB TCS (integrated with WAKE radiator) into the AMS02 system.
AMS-CAB-TCS-3.5 -030	CAB TCS integration Jig	A suitable Integration jig shall be designed to integrate the CAB TCS into AMS system.	ROD	It shall be considered the possibility that the CAB LHP system is mounted on the radiator without the CAB installed, and a mechanical sustain able to keep the evaporators in place up to the CAB installation may be provided.

TESTING

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-3.5 -040	CAB TCS system mass	The weight of all the CAB TCS ready-to-fly parts shall be properly verified.	Test	**Applicable to LHP supplier**

4. LOOP HEAT PIPE REQUIREMENTS

Regarding the temperature requirements, unless otherwise specified in the text, by "*evaporator temperature*" we shall consider the temperature of the interface of the evaporator to the CAB base-plate on the evaporator side (i.e. evaporator saddle).

4.1 GENERAL REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.1 -010	Product Assurance	CAB LHPs shall be designed, manufactured and verified according to the PA Plan of the LHP provider, which shall be approved by CGS at beginning of the contract.	ROD, Analysis, Inspection	*Exceptions can be tolerated from case to case after approval by CGS* **Applicable to LHP supplier**

4.2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.2 -010	Heat Transport Capability	***Required*** Heat Transport Capability (HTC) is 350Watt min per each LHP. at the maximum temperature of 55.5°C at evaporator interface (saddle side)	Analysis	The condenser heat sink temperature to be used shall be agreed with the LHP supplier. **Applicable to LHP supplier**
AMS-CAB-TCS-4.2 -020	Maximum Heat Transport Capability	The maximum heat transport of a single LHP in the evaporator temperature range -30°C to +50°C (LHP Heat Transport curve) shall be determined under an agreed condenser sink temperature. At each evaporator temperature the heat transport shall be increased as long as one of the following limits is reached: 1) HTC is higher than 350W 2) a temperature of +50°C is reached on the evaporator	Analysis, Test	The supplier is requested to provide plots of the measured LHP capacity. The condenser heat sink temperature to be used shall be agreed with the LHP supplier. Each LHP shall be tested separately. **Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.2-030	LHP Start-up heater power	Each LHP shall have to start-up with minimum 5 W (supplied at the minimum voltage of 113Vdc) heater power at every evaporator temperature in the temperature range of CAB.	Test	Each LHP shall be tested separately **Applicable to LHP supplier**
AMS-CAB-TCS-4.2-040	Heaters power density	The Start-Up Heater power density shall not exceed 0,465W/cm2 (3W/in2) when heaters are supplied at the maximum voltage of 126,5Vdc.	ROD	This power density limit is applicable only if heaters (foil type) are glued. In case the heaters are bolted down with a plate the limit doesn't apply **Applicable to LHP supplier**
AMS-CAB-TCS-4.2-050	LHP Minimum Non Operative Temperature (Freezing)	The LHP minimum non operating temperature shall be as low as -73°C.	RoD and/or similarity	**Applicable to LHP supplier**

4.3 LIFETIME AND RELIABILITY REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.3-010	Life time	The design of the LHPs shall be compatible with a lifetime of 3 (+2) years in orbit and a storage time of 3 years on ground after final Flight Readiness Review (FRR).	Similarity	**Applicable to LHP supplier**
AMS-CAB-TCS-4.3-020	Reliability	Each LHP shall have a known reliability for in-orbit lifetime of 3 (+2) years. A reasonable value (>0.9) will be provided by the LHP supplier.	Similarity	**Applicable to LHP supplier**

4.4 DESIGN REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.4-010	LHP Temperature Reference Point	The LHP Temperature Reference Point (TRP) shall be defined in the Evaporator assembly ICD	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-020	LHP Design	The two LHPs shall be designed according to IF drawings presented in Annex A and Annex B.	Review of Design	The LHP transport lines shall be agreed between LHP supplier and CGS. **Applicable to LHP supplier**
AMS-CAB-TCS-4.4-030	LHP component materials	The LHP shall be made of the following materials : Stainless Steel for the evaporator block (including evaporator body, compensation chamber, valve & transport lines). Nickel for the wick. Aluminum alloy (AlMgSi0.5 or equivalent) for condenser tubing soldered to Al saddle. Ammonia (Purity≥99.95%) as heat carrier.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-040	LHP Declared Material List	All the LHP parts materials shall be properly recorded in the Declared Material List.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-050	Nickel mass estimate	The precise mass estimate of Nickel content shall be provided by the LHP provider, within 5% accuracy.	Review of Design	As a general remark non magnetic material shall be used. If not possible (in particular for wick), precise location and amount of magnetic material (within 5% accuracy) shall be promptly notified. **Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.4-060	Material and Manufacturing process selection	The selection of the LHP materials and manufacturing process shall be such as to avoid material compatibility and structural problems in order to meet the required LHP performance over the specified life time.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-070	LHP manufacturing process CoC	All the LHP manufacturing processes used in the LHP parts shall be covered by standard specification (i.e. ECSS, NASA, MIL, etc..) or by LHP supplier internal specification in line with the required standards. These specifications shall include methods of inspection, tests and acceptance/rejection criteria.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-080	Passive Bypass Valve	Each LHP shall be equipped with a passive by-pass valve, in order to minimize cool-down of the CAB unit after system power outage	Review of Design	**Applicable to LHP supplier** CAB temperature > -40°C after 8 hours power outage.
AMS-CAB-TCS-4.4-090	Passive By-pass valve set-point	The by-pass valve shall prevent the vapor to reach the radiator at a set-point temperature of -10°C	Review of Design	**Applicable to LHP supplier** This lower limit represents the temperature at which the valve is completely OFF (no fluid flow towards condenser)
AMS-CAB-TCS-4.4-100	Passive By-pass valve set-point, EOL	The valve set point in End Of Life (EOL) conditions (due to Argon vessel partial depletion), shall be determined (according to the measured leak rate) considering 3 (+2) years lifetime.	Analysis	**Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.4 -110	LHP bonding	The LHPs shall have a mechanically secure electrical conducting connection to a conductive structure (Class S Bonding) as specified in SSP-30245.	ROD, Test	
AMS-CAB-TCS-4.4 -120	Flight heritage	The LHP supplier shall notify CGS on mechanical load levels the Loop heat Pipe have seen during qualification or similar missions.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4 -130	Weld inspection data	Inspection data shall be provided for all the individual welds , showing that they are compliant to the applicable process specification requirements.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4 -140	Surface Treatment	The LHP parts manufactured from aluminum alloy (i.e. condenser lines, evaporator saddle) shall have the following surface treatment: (ALODINE 1200) according to Mil-C- 5541 Class 3 or equivalent, unless bonding processes require a different treatment (e.g.: anodic coating, sand-blasting) The surface treatments of the LHP parts manufactured from a different material shall be according to applicable standards of space industry and agreed by CGS.	ROD	**Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.4-150	Maximum Design Pressure	Both the LHPs shall be designed for an internal Maximum Design Pressure (MDP), which is equal to the vapor pressure of the working fluid at Maximum Design Temperature (MDT)[4]	Analysis	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-160	Proof pressure definition	The LHPs FM proof pressure shall be equal to 1.5xMDP	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.4-170	Burst Pressure definition	The LHP burst pressure shall be P≥4xMDP	ROD	The LHP design shall be verified to the burst pressure (see relevant requirements in the test section). Deformations are accepted. **Applicable to LHP supplier**

[4] The MDT is calculated under the hottest environmental conditions, , considering two failures and the maximum load applied.

4.5 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.5 -010	LHP MASS	The total wet mass of each LHP shall not exceed 1,3 Kg, including Evaporator assembly (evaporator body, aluminum saddle, compensation chamber, valve and bypass line), transport lines, condenser tubes (including the saddles and the glue if they are bonded to the radiator), heaters, thermostats.	Analysis , Test (End mass verification of flight LHP by weighing).	Fasteners are excluded from this budget. **Applicable to LHP supplier**

4.6 INTERFACE REQUIREMENTS

4.6.1 MECHANICAL INTERFACE REQUIREMENTS

The LHP evaporator saddle mounting surface represents the mechanical interface of the LHP with the CAB base-plate.
The LHP valves and transport lines have support brackets that are mounted on the CAB base-plate as well.
The LHP condenser lines mounting surface represent the mechanical interfaces with the WAKE Radiator.

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.6.1 -010	CAB base-plate / LHP MECHANICAL INTERFACE	The LHP evaporator saddle shall be designed according to the hole pattern available at CAB base-plate level. The mechanical Interface is as per drawing in RD[1]. The mechanical interface shall be identical for each LHP.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.6.1 -020	CAB base-plate / LHP brackets MECHANICAL INTERFACE	The LHP valves and transport lines support brackets shall be designed according to the hole pattern available at CAB base-plate level. The mechanical Interface is as per drawing in RD[1].	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.6.1 -030	LHP / START-UP HEATER MECHANICAL INTERFACE	The LHP shall be designed to accommodate start-up heaters. The mechanical accommodation shall prevent the heater from de-bonding in case the power density limit is exceeded (e.g. heater can be secured by a metallic plate).	ROD	Heaters and relevant provisions shall be delivered by CGS. **Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.6.1 -040	LHP / WAKE radiator MECHANICAL INTERFACE	The LHP condenser lines shall be designed according to the foot print on the WAKE radiator radiative side. The footprint is as per drawing in RD[2]. The foot print is different for the two LHPs.	ROD	**Applicable to LHP supplier**
AMS-CAB-TCS-4.6.1 -050	LHP / WAKE radiator attachment method	The saddles of the LHP condenser lines shall be designed to be riveted and glued to the foot print on the WAKE radiator radiative side as per drawing in RD[2].	ROD,I	Rivets shall be used to secure the condensers to the radiator. These mounting provisions shall be provided by CGS. **Applicable to LHP supplier**

4.6.2 ELECTRICAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.6.2 -010	Heater Voltage	The start-up heaters shall operate and be compatible with the 120Vdc steady state voltage range of 106Vdc to 126.5Vdc.	ROD	
AMS-CAB-TCS-4.6.2 -020	Heater Connector	The LHP start-up heater shall be supplied by Power Distribution System (PDS) via a bracketed connector mounted on the WAKE radiator.	ROD	

4.6.3 THERMAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.6.3 -010	LHP condenser lines / WAKE Radiator contact conductance	The attachment method selected to bond the condenser lines to the WAKE radiator outer skin shall provide a thermal contact conductance greater than 12 W/K per condenser tube meter length	Analysis	
AMS-CAB-TCS-4.6.3 -020	Thermal protection	The transport lines (not directly sunk to the WAKE radiator) of the LHP systems shall be properly insulated from the external environment.	Analysis, Test	
AMS-CAB-TCS-4.6.3 -030	Thermal filler	The LHP evaporators saddles shall be bolted to the CAB base-plate. An interface filler shall be inserted at contact level.	RoD	The Thermal filler shall be procured by CGS

4.7 TESTING AND INSPECTION REQUIREMENTS

The following test requirements shall apply at LHP component level.
It is expected that the vibration transmitted through the primary structure (USS) to the AMS02 components will be smaller than Minimum Workmanship Levels (MWL) listed in Table 4-1. For mission success purpose the AD[2] recommends that vibration testing of the critical components shall be performed to MWL.

Minimum Workmanship Levels for the Alpha Magnetic Spectrometer - 02

All Axes	20 Hz	0.01 g^2/Hz
	20-80 Hz	+3 dB/Octave
	80-500 Hz	0.04 g^2/Hz
	500-2000 Hz	-3 dB/Octave
	2000 Hz	0.01 g^2/Hz
	Overall = 6.8 Grms	

Note: MWL Test duration: 60 seconds per axis

Table 4-1: MWL for the Valve vibration environment

The LHP components have been reviewed under this light and the by-pass valve (actually the valve bellow) has been identified to be the only critical part. For this reason vibrations test at MWL levels (or even higher) shall be part of the valves qualification test campaign (shared with the cryo-cooler TCS program).

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.7 -010	Welding inspections	All the LHP weld junctions shall be He leak inspected.	Test	Any additional weld joint inspection (e.g. X-ray inspection) shall be agreed with CGS case by case. **Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.7-020	Burst tests	Burst Pressure Test shall be performed on samples from same material lot , in particular on: • Bimetallic joint • Filling port pinching • Welding parts • Valve (both chambers).	Test	The burst pressure test shall be performed with representative LHP parts, which are manufactured out of the same material lots as used for flight hardware. Configuration of the test sample shall be agreed with CGS (in particular for what concerns the welding points). The burst pressure samples shall not experience any damage while subjected to the required burst pressure level(= 4xMDP). Permanent deformations are allowed. **Applicable to LHP supplier**
AMS-CAB-TCS-4.7-030	Valve fatigue cycles	The valve shall be able to operate after being tested a number of cycles of 200000 (carried out in the valve qualification campaign).	Similarity	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7-040	Valve performance and characteristics curve	Each FM Valve shall undergo performance tests to ensure that each valve operates properly at the defined set-point and Stroke vs. pressure shall be provided as a characteristics curve for each valve.	Test	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7-050	Valve Leak test	Each FM valve shall be He leak tested	Test	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7-060	Ammonia residual flow through the valve in OFF mode	The LHP manufacturer shall provide the typical residual ammonia flow to the radiator ("leakage") when the valve is in OFF mode (no vapour towards radiator).	Test	The thermal effects due to this residual flow shall be evaluated. **Applicable to LHP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.7 -070	Valve assembly vibration levels	Each FM valve assembly shall withstand vibration levels (Minimum Workmanship Levels) as specified in the AD[2] and reported in Table 4-1.	Similarity5, Analysis	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7 -080	Valve reservoir Argon leakage	The leakage of the Argon (or whatever fluid is used in the valve) towards ambient shall be experimentally evaluated and the corresponding set-point shift derived by calculation.	Test, Analysis	**Applicable to LHP supplier**

The following test requirements shall apply at the LHP system level.

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.7 -090	Proof Pressure test	Proof Pressure (1,5 x MDP) test shall be performed on the two completed CAB LHPs	Test	Each LHP shall be tested separately **Applicable to LHP supplier**
AMS-CAB-TCS-4.7 -100	Leak test	The FM CAB LHPs shall be leak tight and shall not experience a leak greater than (<1 x 10-9 mbar x liter /sec)	Test	Each LHP shall be tested separately **Applicable to LHP supplier**
AMS-CAB-TCS-4.7 -110	Vapor leak test	The CAB LHPs shall be subjected to a Vapor Leak Test after filling and pinching (<3 x 10-8 Scc/s).	Test	**Applicable to LHP supplier**

[5] Similarity to the valve qualification test campaign

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.7-120	Functional Performance Test	The FM CAB LHP shall undergo a functional Performance Test under ambient conditions.	Test	Each LHP shall be tested separately The LHP supplier standard procedure (to be proposed by the LHP supplier) shall be applied. Any deviation shall be agreed with CGS. **Applicable to LHP supplier**
AMS-CAB-TCS-4.7-130	Charged working fluid	The mass of the charged working fluid shall be measured	Test	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7-140	CAB LHP system mass	The weight of all the CAB LHPs ready-to-fly parts shall be properly verified.	Test	**Applicable to LHP supplier**
AMS-CAB-TCS-4.7-150	Inspection after test	The CAB LHPs shall be visual inspected after each test mode	Inspection	**Applicable to LHP supplier**

4.8 TRANSPORT REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-4.8-010	Transportation loads	The LHPs shall sustain following transportation loads, which occur between manufacturing and assembly, without any loss of performance: ▪ Quasi static loads: Xa=+/-2g, Ya=+/-2g, Za=+/-2g,	ROD	**Applicable to LHP supplier**

5. CAB THERMAL H/W REQUIREMENTS

5.1 CAB AND USS MOUNTED HEAT PIPES

5.1.1 DESIGN REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.1 -010	CAB Heat Pipe Design	The CAB shall be equipped with two straight heat pipes to uniform the temperatures along the CAB sides.	Review of Design	
AMS-CAB-TCS-5.1.1 -020	USS Heat Pipe Design	The USS upper trunnion bridge and the Upper VC Interface Joints shall be thermally coupled by means of 3 heat pipes to reduce the thermal resistance at the interface joint and lower down the temperature of the USS part to which the CAB is bolted down.	Review of Design	
AMS-CAB-TCS-5.1.1 -030	HP component materials	The HP shall be made of the following materials : Aluminum alloy (AlMgSi0.5 or equivalent) for the pipes. Ammonia (Purity≥99.95%) as heat carrier.	ROD	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -040	HP Declared Material List	All the HP parts materials shall be properly recorded in the Declared Material List.	ROD	**Applicable to HP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.1 -050	HP Material and Manufacturing process selection	The selection of the HP materials and manufacturing process shall be such as to avoid material compatibility and structural problems in order to meet the required HP performance over the specified life time.	ROD	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -060	HP manufacturing process CoC	All the HP manufacturing processes used in the HP parts shall be covered by standard specification (i.e. ECSS, NASA, MIL, etc..) or by HP supplier internal specification in line with the required standards. These specifications shall include methods of inspection, tests and acceptance/rejection criteria.	ROD	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -070	Heat Pipe Weld inspection data	Inspection data shall be provided for all the individual welds , showing that they are compliant to the applicable process specification requirements.	ROD	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -080	Heat Pipe Surface Treatment	The HP parts manufactured from aluminum alloy shall have the following surface treatment: (ALODINE 1200) according to Mil-C- 5541 Class 3 or equivalent, unless bonding processes require a different treatment (e.g.: anodic coating, sand-blasting)	ROD	**Applicable to HP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.1 -090	Maximum Design Pressure	Both the CAB and the USS HPs shall be designed for an internal Maximum Design Pressure (MDP), which is equal to the vapor pressure of the working fluid at Maximum Design Temperature (MDT)[6]	Analysis	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -100	Proof pressure definition	The HPs FM proof pressure shall be equal to 1.5xMDP	ROD	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.1 -120	Burst Pressure definition	The HP burst pressure shall be P≥4xMDP	ROD	The HP design shall be verified to the burst pressure (see relevant requirements in the test section). **Applicable to HP supplier**

[6] The Heat Pipe MDT is calculated under the hottest environmental conditions, , considering two failures and the maximum load applied.

5.1.2 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.2 -010	Heat Pipe Mass	The total wet mass of the 5 heat pipes (including the USS heat pipe retainer and the glue/filler) shall not exceed 1,6Kg	Analysis , Test (End mass verification of flight LHP by weighing).	Fasteners are excluded from this budget. **Applicable to HP supplier**

5.1.3 INTERFACE REQUIREMENTS

5.1.3.1 MECHANICAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.3.1 -010	CAB base-plate / Heat Pipes Mechanical Interface	The CAB top and rear sides are equipped with an hole pattern to accommodate heat pipes. The mechanical Interface is as per drawing in RD[1].	ROD	**Applicable to HP supplier** The mechanical design foresees 52 inserts of M3x4.5. The inserts are not evenly spaced.
AMS-CAB-TCS-5.1.3.1 -020	USS / Heat Pipes Mechanical Interface	The USS are not equipped with a dedicated hole pattern to accommodate heat pipes. The heat pipes shall be glued to the USS parts and shall have an additional retention method to clamp the pipes to the USS. The mechanical Interface is as per drawing in RD[12].	ROD	

5.1.3.2 THERMAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.3.2 -010	CAB heat pipes to CAB walls contact	The CAB heat pipes shall be bolted to the CAB top and rear sides. An interface filler shall be inserted at contact level.	RoD, I	
AMS-CAB-TCS-5.1.3.2 -020	USS heat pipes to USS mechanical part contact	USS heat pipes shall be glued to the USS parts and the selected glue shall provide a contact conductance greater than 1200 W/m2K	RoD,I	
AMS-CAB-TCS-5.1.3.2 -030	CAB to USS contact	An interface thermal filler shall be inserted at CAB / USS contact level to provide a contact conductance larger than 1000W/m2K	RoD,I	

5.1.4 TESTING AND INSPECTION REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.4 -010	Welding inspections	All the HP weld junctions shall be He leak inspected.	Test	Any additional weld joint inspection (e.g. X-ray inspection) shall be agreed with CGS case by case. **Applicable to HP supplier**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.4 -020	Burst tests	Burst Pressure Test shall be performed on Heat Pipe samples from same material lot	Test	The burst pressure test shall be performed with representative HP parts, which are manufactured out of the same material lots as used for flight hardware. The burst pressure samples shall not experience any damage while subjected to the required burst pressure level(= 4xMDP). **Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -030	Heat pipe performance and characteristics curve	Each FM Heat Pipe shall undergo performance tests to ensure that each Pipe operates properly at the defined set-point and Heat Transport Capability shall be provided as a characteristics curve for each part.	Test	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -040	Heat Pipe Leak test	The FM HPs shall be leak tight and shall not experience a leak greater than (<1 x 10-9 mbar x liter /sec)	Test	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -050	Heat Pipe vibration levels	Each FM Heat Pipe shall withstand vibration levels (Minimum Workmanship Levels) as specified in the AD[2] and reported in Table 4-1.	Similarity7, Analysis	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -060	Proof Pressure test	Proof Pressure (1,5 x MDP) test shall be performed on all the Heat pipes.	Test	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -070	Vapor leak test	The FM HPs shall be subjected to a Vapor Leak Test after filling and pinching (<3 x 10-8 Scc/s).	Test	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -080	Charged working fluid	The mass of the charged working fluid shall be measured	Test	**Applicable to HP supplier**

[7] Similarity to Heat Pipe supplier data for other test campaign

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.4 -090	Heat Pipes mass	The weight of all the HPs ready-to-fly parts shall be properly verified.	Test	**Applicable to HP supplier**
AMS-CAB-TCS-5.1.4 -100	Inspection after test	The heat pipes shall be visual inspected after each test mode	Inspection	**Applicable to HP supplier**

5.1.5 TRANSPORT REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.1.5 -010	Transportation loads	The HPs shall sustain following transportation loads, which occur between manufacturing and assembly, without any loss of performance: ▪ Quasi static loads: Xa=+/-2g, Ya=+/-2g, Za=+/-2g,	ROD	**Applicable to HP supplier**

5.2 CAB HEATERS AND THERMOSTATS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.2 -010	CAB Heaters	CAB heaters shall bring the CAB unit to the minimum switch-on temperature -20°C, under the coldest environment	Analysis, Test	
AMS-CAB-TCS-5.2 -020	CAB Heaters power density	The CAB Heater power density shall not exceed 0,465W/cm2 (3W/in2) when heaters are supplied at the maximum voltage of 126,5Vdc.	ROD	This power density limit is applicable only if heaters (foil type) are glued. In case the heaters are bolted down with a plate the limit doesn't apply

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.2 -030	CAB Thermostats	CAB Heater operation shall be controlled by mechanical thermostats, bolted down on the CAB base-plate.	RoD, A	
AMS-CAB-TCS-5.2 -040	CAB Heater Voltage	The CAB heaters shall operate and be compatible with the 120Vdc steady state voltage range of 106Vdc to 126.5Vdc.	ROD	
AMS-CAB-TCS-5.2 -050	CAB Heater Connector	The CAB heater shall be supplied by Power Distribution System (PDS) via a bracketed connector mounted on the CAB base-plate	ROD	

5.3 CAB MLI AND THERMAL TAPE

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CAB-TCS-5.3 -010	CAB MLI	MLI blanket shall cover the upper and lower CAB sides.	RoD, I	
AMS-CAB-TCS-5.3 -020	CAB tape	CAB external faces shall be covered by Silver Teflon Tape. The tape shall be cut in patches, each of shall not exceed a individual surface of 200cm2.	RoD,I	

6. DELIVERABLES

6.1 DELIVERABLE H/W

The CAB TCS hardware to be produced and delivered shall consists of:
2 complete LHP systems composed by:

Part	Quantity	Supplier	Remarks
Evaporator assy	2	LHP supplier	Including the saddle
Compensation chamber	2	LHP supplier	
Valve and valve brackets	2	LHP supplier	Including Argon
Transport lines	4	LHP supplier	
Condenser lines	2	LHP supplier	Including the saddles
Condenser lines glue and rivets	As needed	CGS	Specified by CGS
Working fluid	As needed to fill the loops	LHP supplier	Ammonia
LHP Start-up heaters	2	CGS	Specified by LHP supplier
LHP Start-up Heater cabling	As needed	CGS	CGS is responsible for the cabling connecting the heater circuit to the intermediate circular connector.
LHP start-up heater connector bracket	1	AMS Collaboration	Designed by CGS
LHP start-up heater connector	2	CGS	Specified by CGS
MLI blanket around the transport lines not directly bolted down to the structure	As needed	CGS	Specified by CGS
Fasteners	As needed	CGS	Specified by CGS/CRISA
CAB LHP Transportation Jig	2	LHP supplier	
Integration Jig	1	CGS	
CAB LHP Transport container	2 (TBC)	LHP supplier	

Table 6-1 CAB LHP Deliverable H/W items

CAB Thermal H/W directly mounted on CAB unit composed by :

Part	Quantity	Supplier	Remarks
CAB Thermostats	4	CGS	Specified by CGS
CAB Heaters	2	CGS	Specified by CGS
CAB Heater/Thermostat cabling	As needed	CGS	CGS is responsible for the cabling connecting the heater/thermostat circuit to the intermediate circular connector.
CAB heater/thermostat connector bracket	1	CGS	Designed by CRISA
CAB heater/thermostat connector	1	CGS	Specified by CGS
CAB chassis thermal coating	As needed to cover the CAB radiative surfaces	CGS	Specified by CGS
DTS (Temperature sensors) + sensor cabling	3 (TBC)	AMS Collaboration	Location Specified by CRISA/CGS AMS Collaboration is responsible for the thermal sensor installation.
CAB straight heat pipes	2	Heat Pipe Supplier	Specified by CGS
Thermal filler between heat pipes and CAB chassis	As needed	CGS	Specified by CGS
Thermal filler between CAB chassis and USS	As needed	CGS	Specified by CGS
CAB MLI + grounding	As needed	CGS	Specified by CGS
Fasteners (Heat pipe + connector bracket + connector + thermostat fixation)	As needed	CGS	Specified by CGS

Table 6-2 CAB Thermal Harware Deliverable H/W items

CAB Thermal H/W mounted on USS composed by :

Part	Quantity	Supplier	Remarks
USS heat pipes	3	Heat Pipe Supplier	Specified by CGS
USS heat pipes glue	As needed	CGS	Specified by CGS
USS heat pipe retainers	As needed	CGS	Designed by CGS
USS heat pipe retainers fasteners	As needed	CGS	Specified by CGS

Table 6-3 CAB Thermal Harware (mounted on USS) Deliverable H/W items

6.2 DELIVERABLE DOCUMENTS

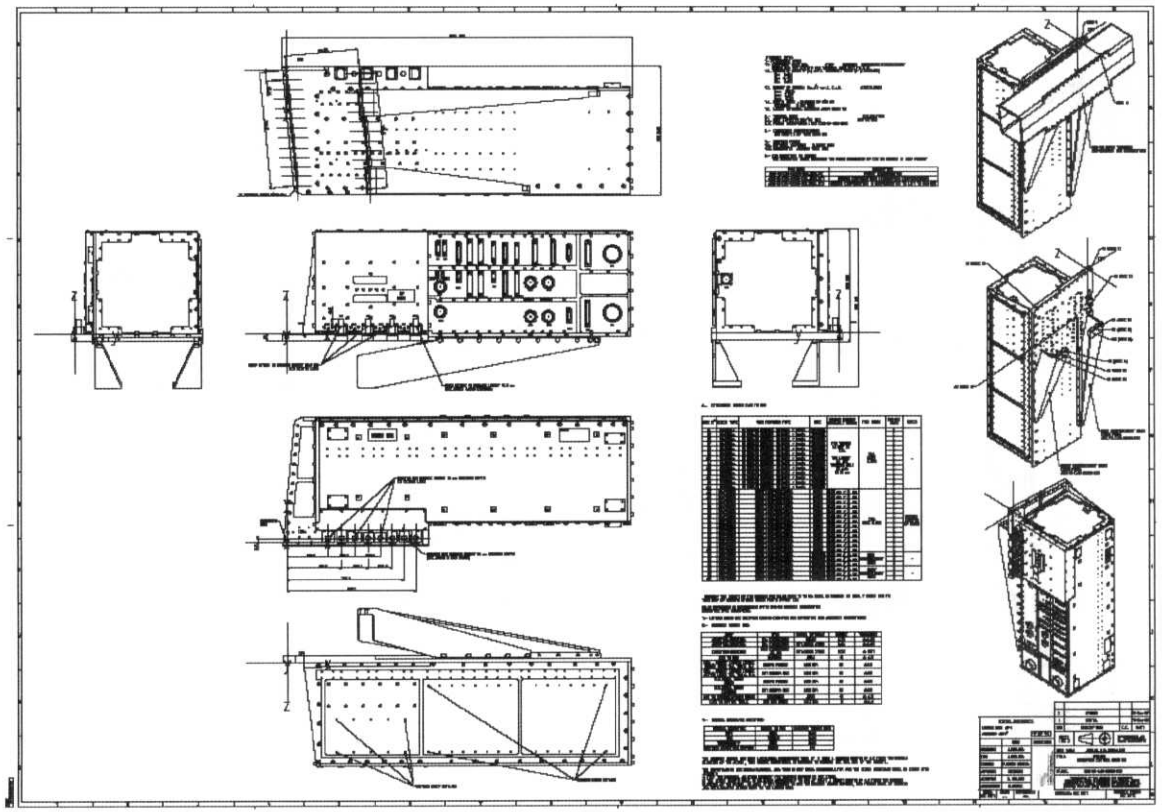
Part	Supplier	Remarks
Declared Material, Component and Process List	LHP supplier / CGS	
LHP system Certificate Of Conformance	LHP supplier	The LHP supplier shall provide Certificates of Conformance for each LHP system for: • Purity of Ammonia • Filling quantity (According to fill analysis) • Successful acceptance pressure and leak test • Successful burst pressure on selected components • Mass measurement of the LHP parts according to estimated mass budget
Pa Plan	LHP supplier	
Valve qualification test report	LHP supplier	The qualification campaign of the valve shall be properly documented
Acceptance test plan and procedures	LHP supplier	
Test Report	LHP supplier	All the requirements that are supposed to be verified by test shall be properly documented.
Inspection reports	LHP supplier	Weld inspection report
Mass measurement	LHP supplier / CGS	
Management documentation	LHP supplier	- Minutes of Meeting. - Progress Report (bi-monthly) including: o Action Item Status List.

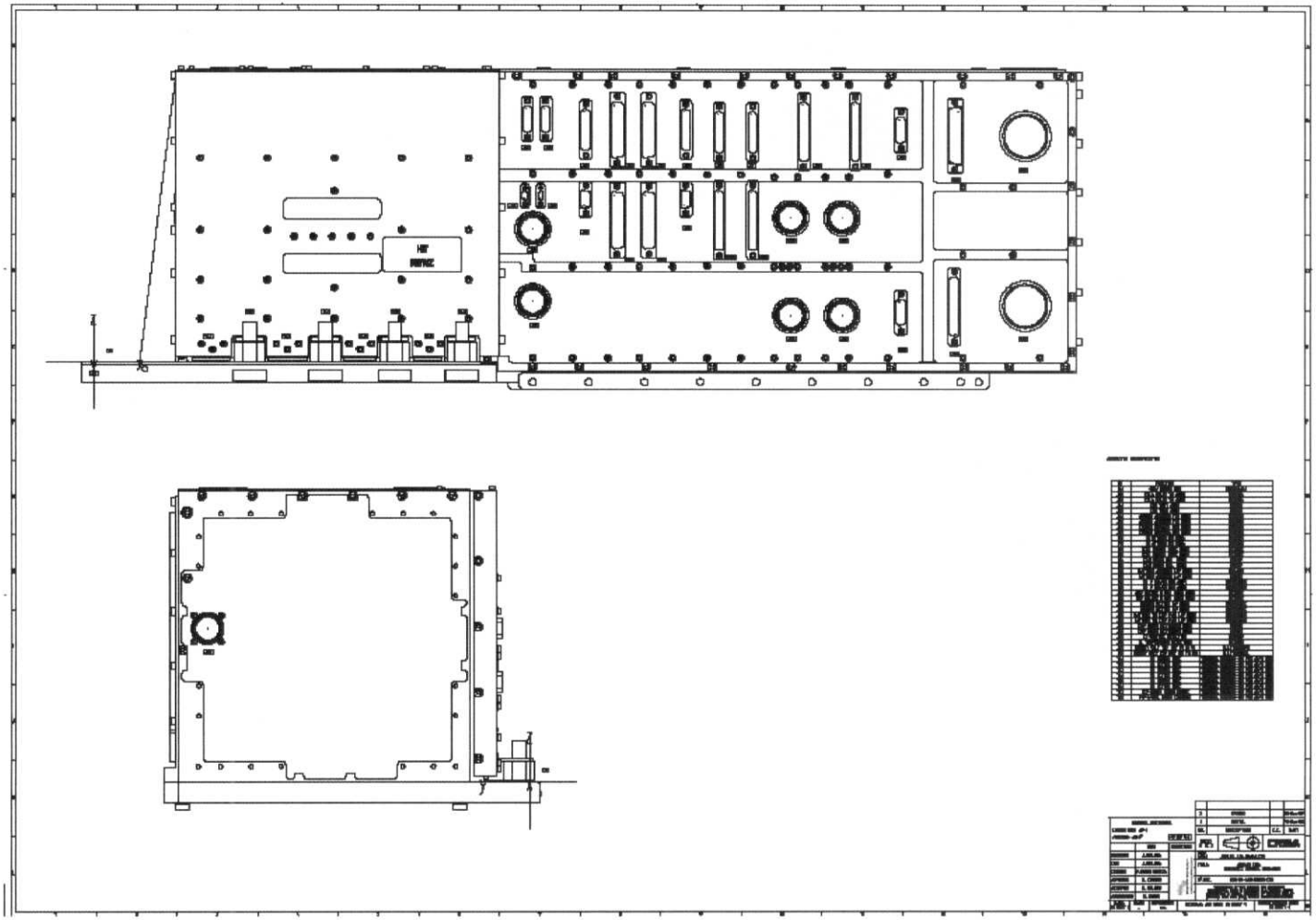
		○ Master Bar Chart. ○ NCR List ○ Shipment Announcement.
CAB TCS thermal analysis report	LHP supplier / CGS	
CAB TCS thermal design report	LHP supplier / CGS	Including budget report
CAB LHP ICD	LHP supplier	
CAB LHP handling, Transportation and Storage procedures	LHP supplier	
CAB TCS Integration procedure	CGS	

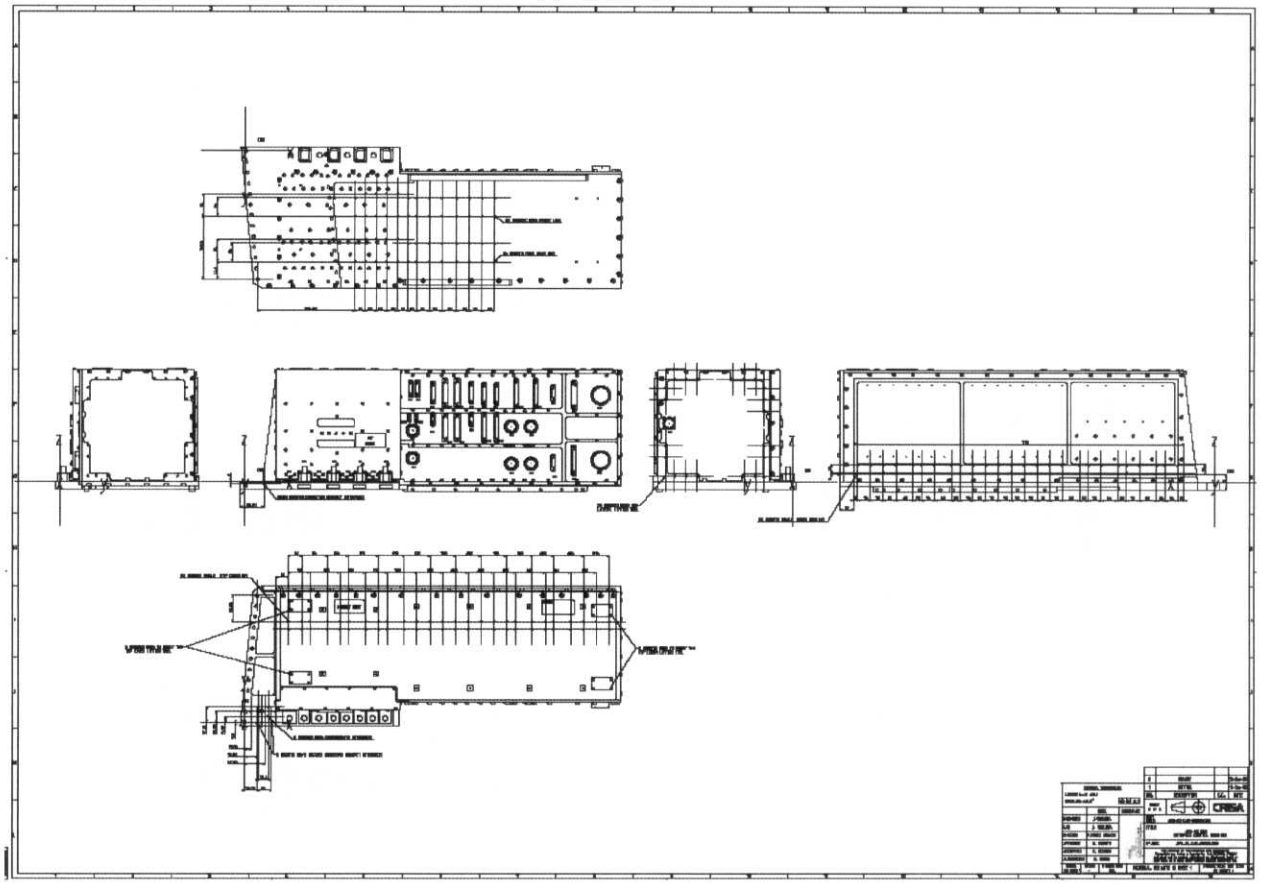
Table 6-4 Deliverable documentation

ANNEX A: CAB INTERFACE CONTROL DRAWING

The following figure shows the CAB mechanical interface Drawing (RD[1]):







ANNEX B: WAKE RADIATOR INTERFACE CONTROL DRAWING

The following figure shows the WAKE Radiator mechanical interface Drawing (RD[2]):